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Musil

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(54) **METHOD AND APPARATUS FOR CONTROLLING DUST EMISSIONS WITH TEMPERATURE CONTROL**

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E01C 23/14 (2006.01)
E01C 23/088 (2006.01)

(52) **U.S. Cl.**
CPC ***E01C 23/088*** (2013.01); *E01C 2301/50* (2013.01)

(58) **Field of Classification Search**
USPC 404/94, 95
IPC E01C 23/127,23/14
See application file for complete search history.

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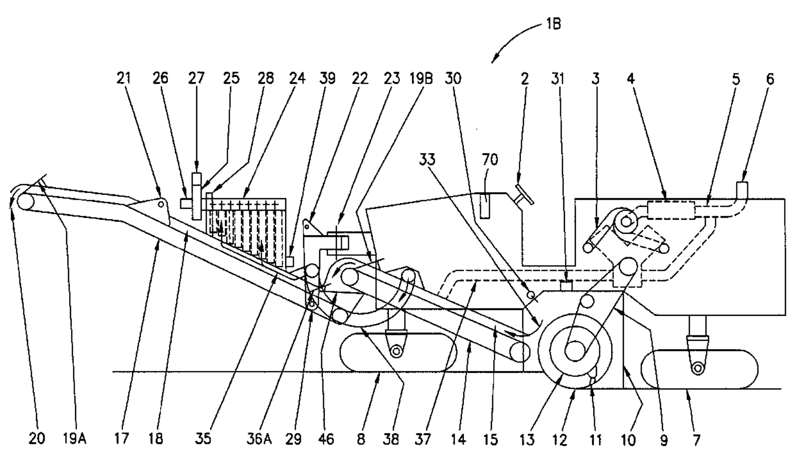
(57) **ABSTRACT**

A working machine for use in milling the surface of a road includes a drive engine that produces engine exhaust gases. The working machine also includes a milling drum that is mounted for rotation against the surface of the road so as to generate milled material including dust from the road surface. The milling drum is contained within a milling chamber, and a spray assembly directs water into the milling chamber in such a manner that, during a period of rotation of the milling drum against the surface of the road, at least a portion of the water is converted to a vapor. A conduit is provided for conducting at least a portion of the engine exhaust gases into an enclosed space in communication with the milling chamber to raise the temperature of a gas stream therein containing vapor and dust from the milled material.

18 Claims, 9 Drawing Sheets



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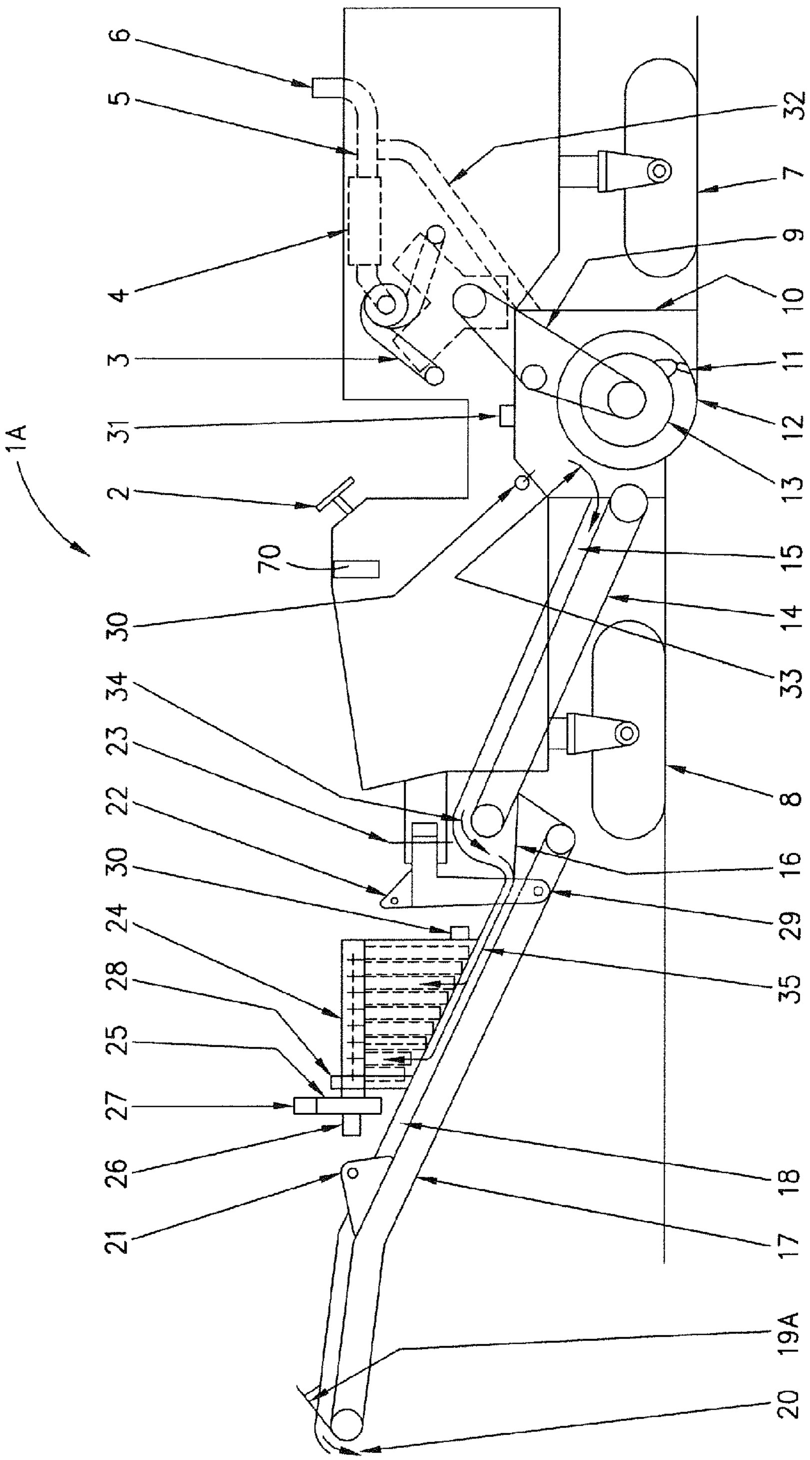
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FIGURE 1

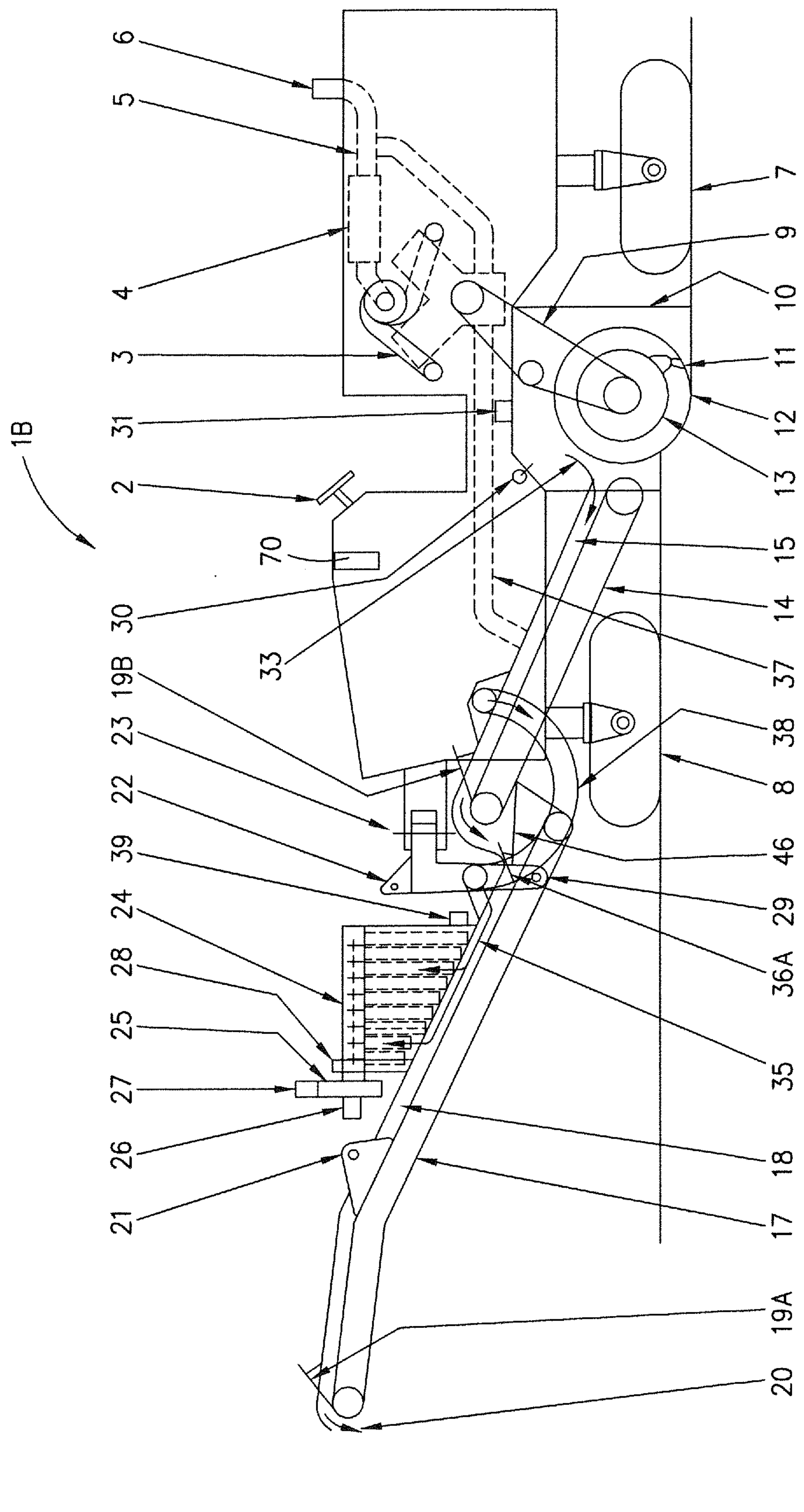

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FIGURE 2

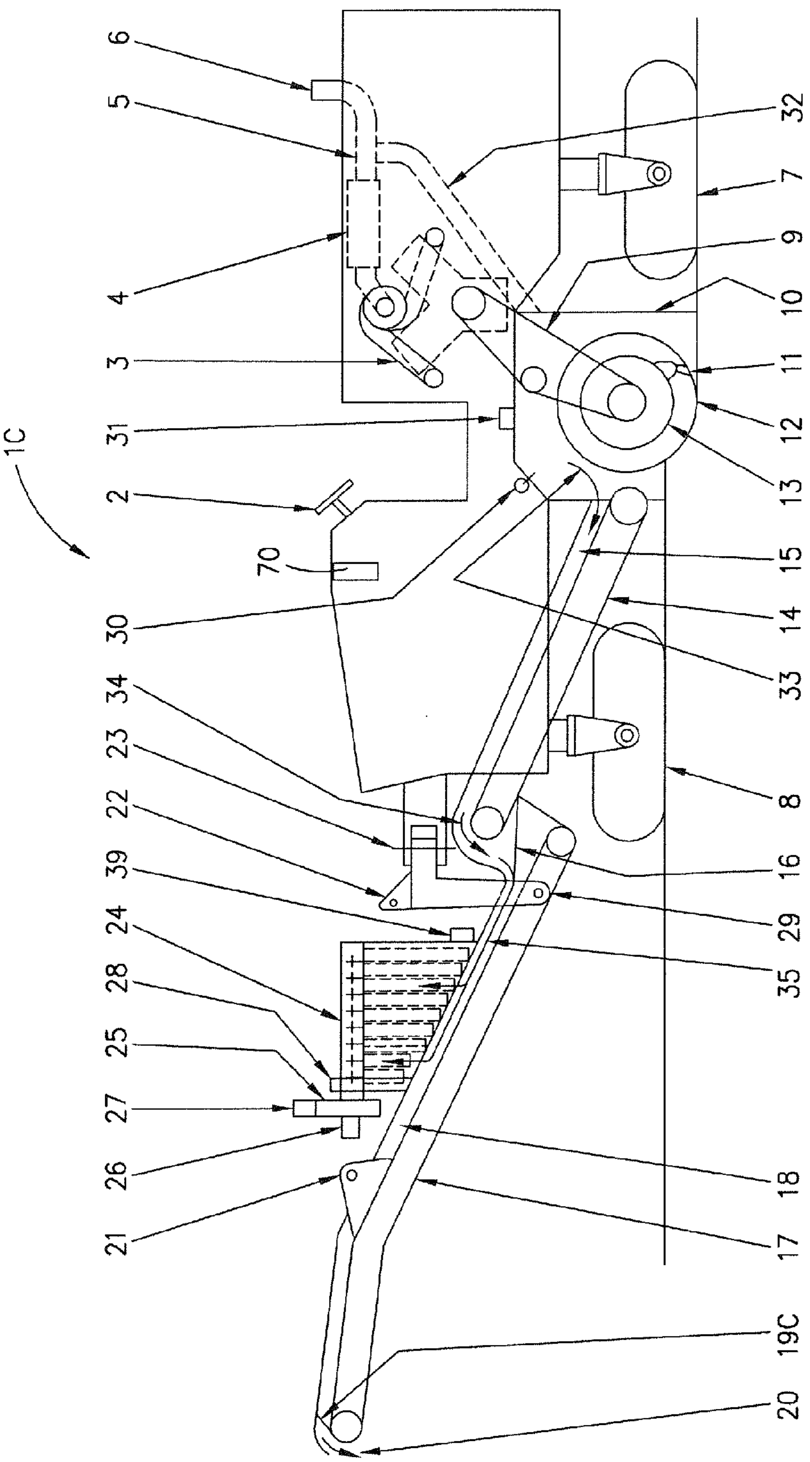
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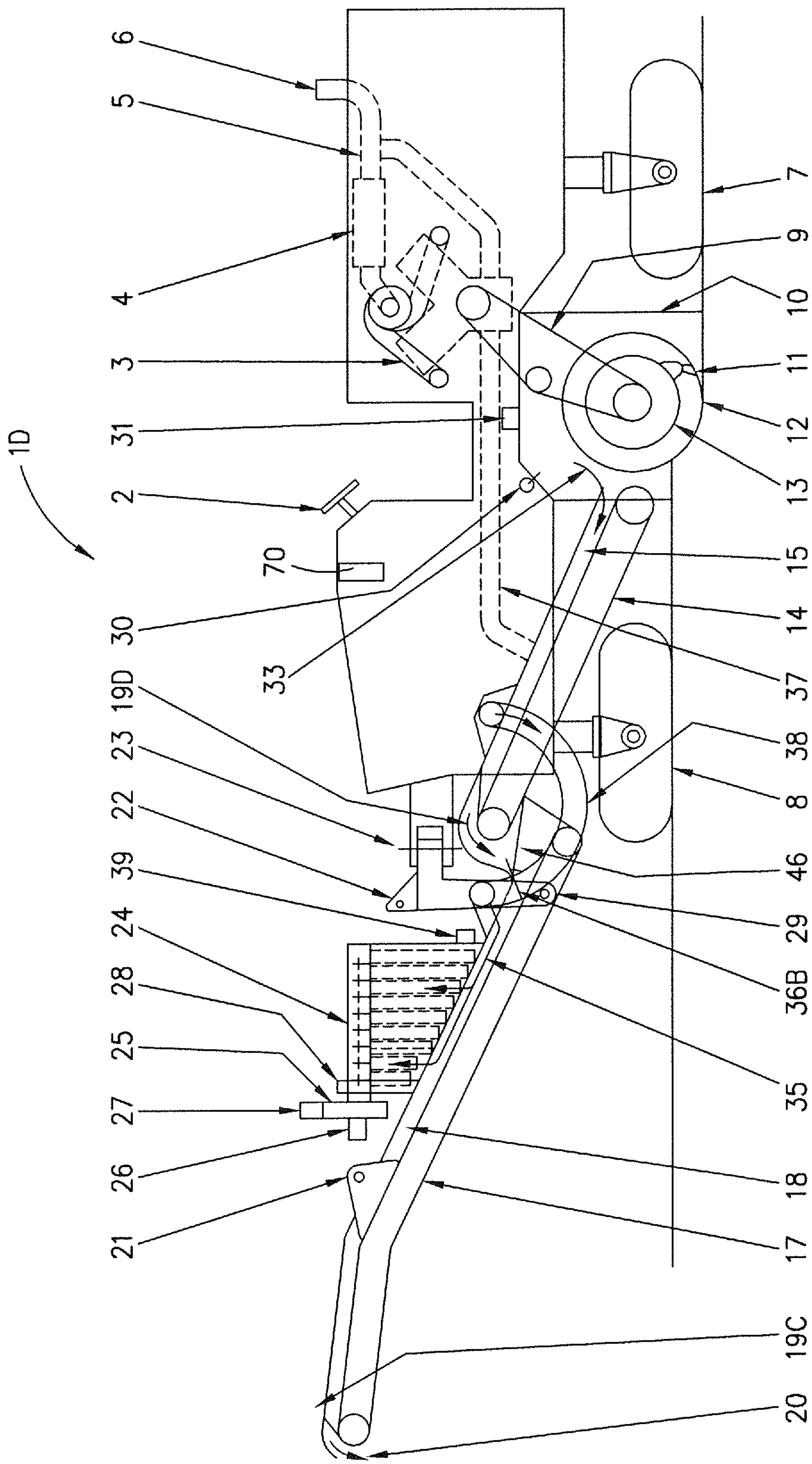
FIGURE 3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19C
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FIGURE 4

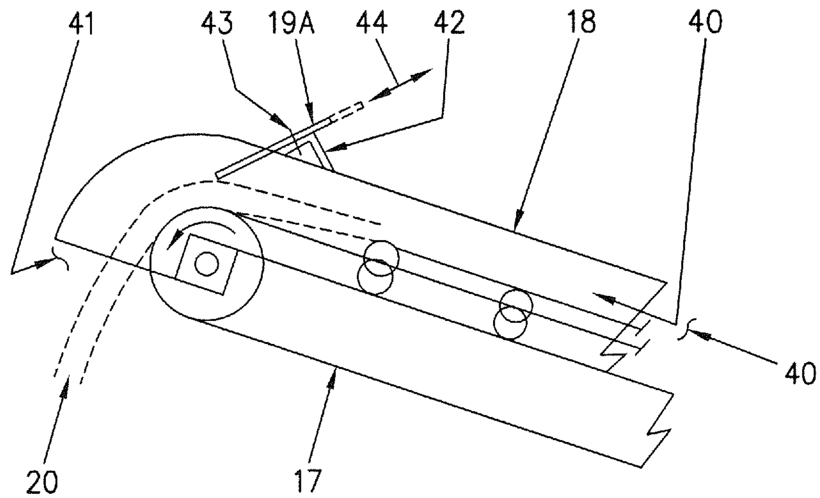

FIGURE 5

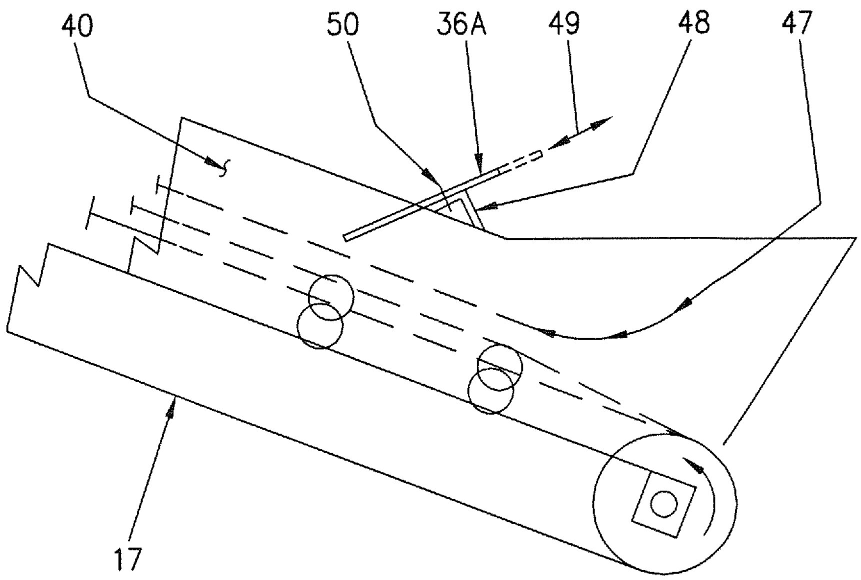

FIGURE 6

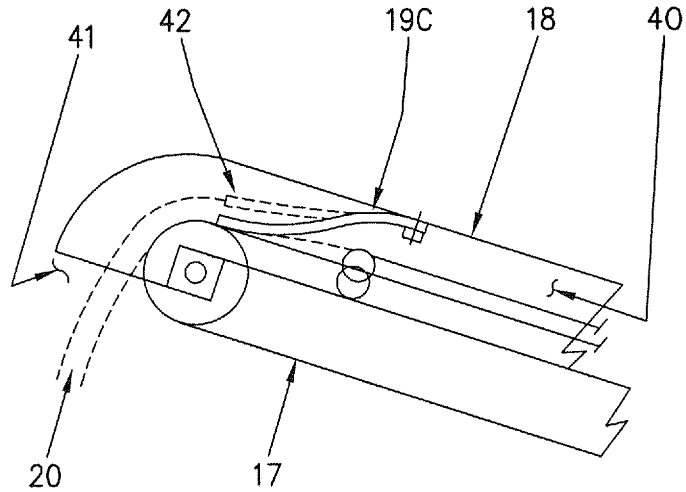

FIGURE 7

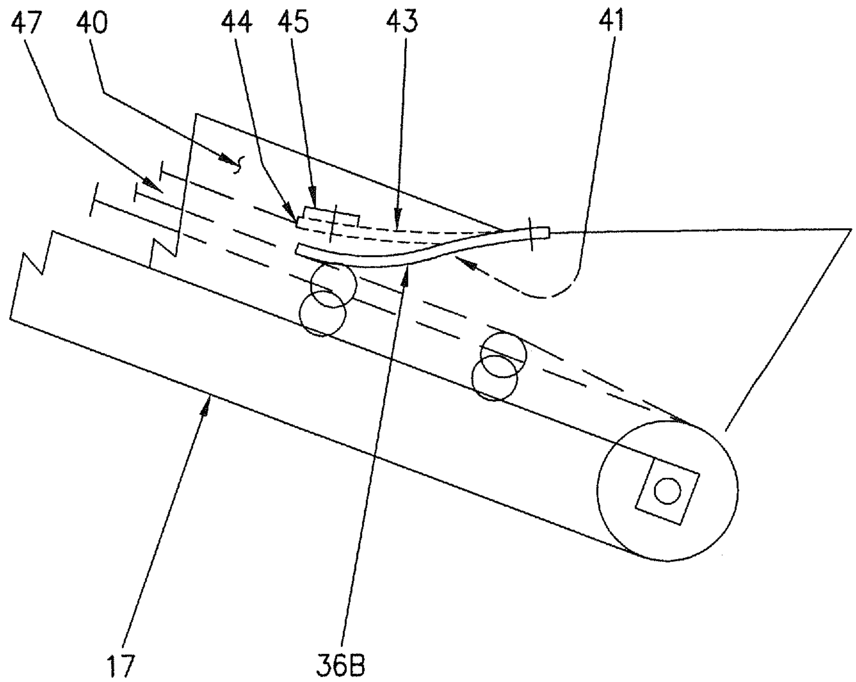

FIGURE 8

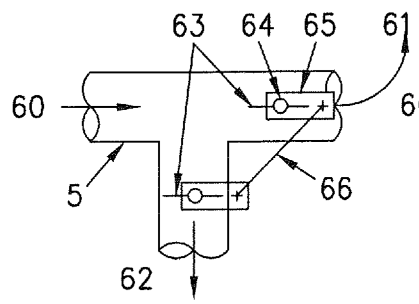

FIGURE 9A

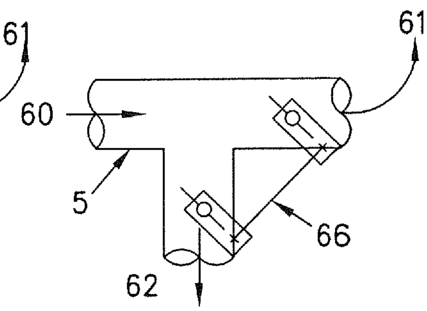

FIGURE 9B

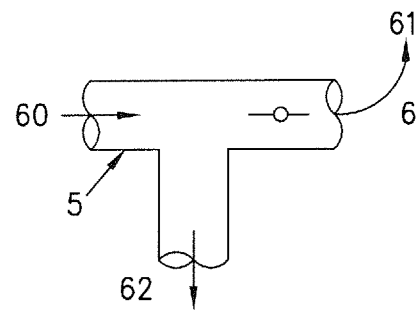

FIGURE 10A

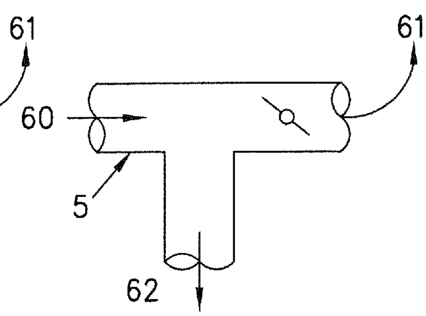

FIGURE 10B

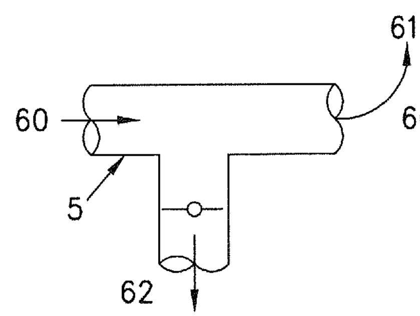

FIGURE 11A

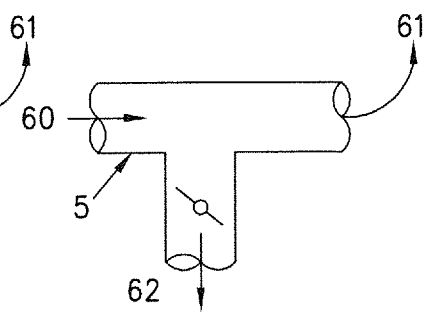

FIGURE 11B

METHOD AND APPARATUS FOR CONTROLLING DUST EMISSIONS WITH TEMPERATURE CONTROL

CROSS-REFERENCE TO RELATED APPLICATION

This application claims the benefit of U.S. Provisional Patent Application No. 61/891,635 which was filed on Oct. 16, 2013, and U.S. Provisional Patent Application No. 61/945,602 which was filed on Feb. 27, 2014.

FIELD OF THE INVENTION

This invention comprises a method and apparatus for raising the temperature of a gas stream that may contain water vapor and dust in a system, in a controlled manner, to a temperature at which mudding does not occur. The invention is useful for preventing ductwork mudding in systems without filtration devices and also in systems with filtration devices.

BACKGROUND OF THE INVENTION

A road milling machine includes a milling drum with a plurality of cutter teeth mounted thereon which is contained within a milling enclosure or chamber. The milling machine is adapted to be advanced across a road surface to "mill" the surface to remove asphaltic or Portland cement concrete road pavement in preparation for recycling the pavement and/or in preparation for applying a pavement overlay. Road milling machines can also be used to "profile" or make smooth an asphalt or concrete road surface. The typical milling machine includes one or more conveyors to take the milled material from the vicinity of the milling drum and direct it away from the machine and into an adjacent dump truck. A road stabilizer/reclaimer machine is similar to a milling machine in that it comprises a wheeled or track-driven vehicle that includes a milling drum with a plurality of cutter teeth mounted thereon which is contained within a milling enclosure or chamber. However, the milling drum of a road stabilizer/reclaimer machine is generally employed to mill or pulverized an existing road bed or roadway to a greater depth than does a milling machine prior to repaving (usually called reclaiming) or prior to initial paving (usually called stabilizing), and it leaves the pulverized material in place. During the operation of a milling machine or a road stabilizer/reclaimer machine, the surface pavement is broken by the cutter teeth of the milling drum, thereby generating dust in the milling chamber.

The cutter teeth on the milling drum of a milling machine or a road stabilizer/reclaimer machine are typically made of metallic carbides or other very hard materials. As these teeth are forced through the road surface as the milling drum is rotated, they are heated by friction to a high temperature. A water spray bar with nozzles is typically mounted within or adjacent to the milling chamber to direct water to cool the hot cutter teeth and/or to control dust emissions. When this cooling water hits the cutter teeth, some of the water is turned into steam. The change in phase of water to steam creates volumetric expansion, and some of the dust and gas stream contents of the milling chamber can be blown out through gaps between the milling chamber and the road surface. Some of the dust that is blown out of or escapes the milling chamber of a milling machine or a road stabilizer/reclaimer machine can contain silica, which in certain forms comprises a health concern for the machine operators and other nearby personnel. To minimize or prevent the escape of the particulate silica and other dust from the milling chamber, it is known to equip the working machine with an emission control system. In some such systems, the dust and its entraining gas stream are routed to an area of safe discharge or to a dust separation device such as a filter assembly where the dust is separated from the entraining gas stream. In some such systems, the milling chamber is placed under a negative pressure using a fan device.

The critical importance of the temperature of the gas stream that contains water in a vapor (gaseous) state and dust generated during milling of a roadway for the efficient operation of an emission control system has not been appreciated. If the temperature of the gas stream is not high enough, the temperature of the gaseous water vapor in the gas stream may fall below its dew point so that the water vapor will condense to a liquid state. This can lead to mudding and fouling of ductwork and to mudding and fouling of separation and filtering devices such as cartridge filters, cyclones, baghouses and other devices. It would be advantageous if a method and apparatus could be developed for control of the temperature of the gas stream entraining dust generated during the milling of a roadway to insure efficient operation of an associated emission control system. Although the invention described herein may be employed in connection with an emission control system including a dust collection device in a working machine such as a milling machine or a road stabilizer/reclaimer machine, it may also be employed in connection with emission control systems with no dust collection device.

Notes on Construction

The use of the terms "a", "an", "the" and similar terms in the context of describing the invention are to be construed to cover both the singular and the plural, unless otherwise indicated herein or clearly contradicted by context. The terms "comprising", "having", "including" and "containing" are to be construed as open-ended terms (i.e., meaning "including, but not limited to,") unless otherwise noted. The terms "substantially", "generally" and other words of degree are relative modifiers intended to indicate permissible variation from the characteristic so modified. The use of such terms in describing a physical or functional characteristic of the invention is not intended to limit such characteristic to the absolute value which the term modifies, but rather to provide an approximation of the value of such physical or functional characteristic. All methods described herein can be performed in any suitable order unless otherwise specified herein or clearly indicated by context.

The use of any and all examples or exemplary language (e.g., "such as" and "preferably") herein is intended merely to better illuminate the invention and the preferred embodiments thereof, and not to place a limitation on the scope of the invention. Nothing in the specification should be construed as indicating any element as essential to the practice of the invention unless so stated with specificity.

Various terms are specifically defined herein. These terms are to be given their broadest possible construction consistent with such definitions, as follows:

The term "water" refers to a fluid that is primarily or wholly comprised of water or a solution, emulsion or mixture in which water is the primary component.

The terms "steam", "water vapor", "vapor" and similar terms refer to water in a gaseous state.

The term "gas stream" refers to a stream or flow of a gas which may include air and water vapor.

The term "dust" refers to particulate material that can be entrained in a gas stream.

The term "working machine" refers to a milling machine and/or a stabilizer/reclaimer machine and/or any other road working machine that includes a milling drum and a spray assembly for use in dispensing water for heat and/or dust control.

The terms "upper", "top" and similar terms, when used in reference to a relative position or direction on or with respect to a working machine, or a component or portion of such a machine, refer to a relative position or direction that is farther away from the surface on which the working machine is placed for operation.

The terms "lower", "bottom" and similar terms, when used in reference to a relative position or direction on or with respect to a working machine, or a component or portion of such a machine, refer to a relative position or direction that is nearer to the surface on which the working machine is placed for operation.

The term "front end" and similar terms, when used in connection with a working machine or a component or portion of such a machine, refer to the end of the machine, or the component or portion thereof which is in the direction of travel of the machine while it is being operated.

The terms "forward", "in front of", and similar terms, as used herein to describe a relative position or direction on or in connection with a working machine, or a component or portion of such a machine, refer to a relative position or direction towards the front end of the machine.

The terms "back end", "rear end" and similar terms, when used in connection with a working machine or a component or portion of such a machine, refer to the end of the machine or the component or portion thereof which is farther from the front end of the working machine.

The terms "rearward", "behind", and similar terms, as used herein to describe a relative position or direction on or in connection with a working machine, or a component or portion of such a machine, refer to a relative position or direction towards the rear end of the machine.

The term "linear actuator" refers to an electric, hydraulic, electro-hydraulic or mechanical device that generates force which is directed in a straight line. One common example of a "linear actuator" is a hydraulic actuator which includes a cylinder, a piston within the cylinder, and a rod attached to the piston. By increasing the pressure within the cylinder on one side of the piston (over that on the opposite side of the piston), the rod will extend from the cylinder or retract into the cylinder.

The term "rotary actuator" refers to an electric, hydraulic or electro-hydraulic motor or other device that generates force that is directed along an arc or about a center of rotation.

The term "actuator" refers to a linear actuator or a rotary actuator.

SUMMARY OF THE INVENTION

The invention comprises a working machine for use in milling the surface of a road, which working machine includes a drive engine that produces engine exhaust gases and a milling drum that is mounted for rotation against the surface of the road so as to generate milled material including dust from the road surface. The milling drum is contained within a milling chamber, and a spray assembly is provided for directing water into the milling chamber in such a manner that, during a period of rotation of the milling drum against the surface of the road, at least a portion of the water is converted to a vapor. An enclosed space comprises the milling chamber, and a conduit is provided for conducting at least a portion of the engine exhaust gases into the enclosed space to raise the temperature of a gas stream therein containing vapor and dust from the milled material.

The invention also comprises a method for operating such a working machine by conducting at least a portion of the heat from the engine exhaust gases into the enclosed space to raise the temperature of a gas stream therein containing vapor and dust from the milled material.

In order to facilitate an understanding of the invention, the preferred embodiments of the invention, as well as the best modes known by the inventors for carrying out the invention, are illustrated in the drawings, and a detailed description thereof follows. It is not intended, however, that the invention be limited to the particular embodiments described or to use in connection with the apparatus illustrated herein. Therefore, the scope of the invention contemplated by the inventors includes all equivalents of the subject matter recited in the claims, as well as various modifications and alternative embodiments such as would ordinarily occur to one skilled in the art to which the invention relates. The inventors expect skilled artisans to employ such variations as seem to them appropriate, including the practice of the invention otherwise than as specifically described herein. In addition, any combination of the elements and components of the invention described herein in any possible variation is encompassed by the invention, unless otherwise indicated herein or clearly excluded by context.

BRIEF DESCRIPTION OF THE DRAWINGS

The presently preferred embodiments of the invention are illustrated in the accompanying drawings, in which:

FIG. **1** is a side view, partially in section, of a milling machine that is equipped with an embodiment of the invention.

FIG. **2** is a side view, partially in section, of a milling machine of a different configuration from that of FIG. **1** that is also equipped with an embodiment of the invention that is similar to that of the embodiment of FIG. **1**.

FIG. **3** is a side view, partially in section, of a milling machine that is equipped with another embodiment of the invention.

FIG. **4** is a side view, partially in section, of a milling machine of a different configuration from that of FIG. **3** that is also equipped with an embodiment of the invention that is similar to that of the embodiment of FIG. **3**.

FIG. **5** is a side view, partially in section, of an adjustable damper plate of the embodiments of the invention shown in FIGS. **1** and **2**.

FIG. **6** is a side view, partially in section, of an adjustable damper plate of the embodiment of the invention shown in FIG. **2**.

FIG. **7** is a side view, partially in section, of a flap seal of the embodiments of the invention shown in FIGS. **3** and **4**.

FIG. **8** is a side view, partially in section, of a flap seal of the embodiment of the invention shown in FIG. **4**.

FIG. **9**A illustrates a dual damper embodiment of the exhaust metering valve of a preferred embodiment of the invention in which dampers are provided in the exhaust port and the emission system supply port, and the dampers are shown in the first position.

FIG. **9**B illustrates the dual damper embodiment of FIG. **9**A, but with the dampers shown in the second position.

FIG. **10**A illustrates a single damper embodiment of the exhaust metering valve of a preferred embodiment of the invention in which the damper is provided in the exhaust port, and the damper is shown in the first position.

FIG. **10**B illustrates the single damper embodiment of FIG. **10**A, but with the damper shown in the second position.

FIG. **11**A illustrates a single damper embodiment of the exhaust metering valve of a preferred embodiment of the invention in which the damper is provided in the emission system supply port, and the damper is shown in the first position.

FIG. **11**B illustrates the single damper embodiment of FIG. **11**A, but with the damper shown in the second position.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Milling machines **1**A, **1**B, **1**C and **1**D, all of which are similar, are illustrated in FIGS. **1**-**4**, respectively. Each of these milling machines includes operator's station **2** and engine **3**, typically a diesel engine. Operator's station **2** includes all of the controls necessary for driving and steering the milling machine, rotating milling drum **13**, and controlling certain aspects of the invention, as explained hereinafter. Power from engine **3** is transmitted by drive belt **9** to milling drum **13**, which is located in enclosed milling chamber **10**. Milling drum **13** includes a plurality of cutter teeth **11** that are adapted to mill the road surface as the milling drum rotates and the machine is advanced along the roadway. The bottom **12** of the milling cut path coincides with the lower portion of the circular cutter tooth path inscribed by the plurality of cutter teeth **11** as milling drum **13** rotates.

Power from engine **3** is also transmitted by means known to those having ordinary skill in the art to which the invention relates to rear track assembly **7** and front track assembly **8**. Milling machines **1**A, **1**B, **1**C and **1**D may include one or two rear tracks, each of which can be turned to the left and to the right for steering purposes. Most commonly, these rear tracks can also be raised and lowered relative to the machine main frame. Typically, there are also two front track assemblies (such as assembly **8**), each of which can be turned to the left and to the right for steering purposes, and each of which can also be raised and lowered relative to the machine main frame. Other embodiments of working machines (not shown in the drawings) include wheel drive assemblies.

Milling chamber **10** has front, rear and side slide covers that contact the road surface and provide a seal against the escape of dust when maintained against the road surface. Milled material is carried up and around the interior of the milling chamber by rotation of the drum and passes through an opening on the front wall, as indicated by arrow **33**, where it is deposited onto the first conveyor **14**. Manifold **30** includes a plurality of nozzles which are in fluid communication with a source of water (not shown) to allow cooling water to be sprayed into the milling chamber to cool cutting teeth **11**.

In the preferred embodiments of the milling machines illustrated in the drawings, fan **25** is provided to create negative (or suction) pressure within the milling chamber (as described in more detail hereinafter). A first sensor is mounted at sensor location **31** in the milling chamber to measure the level of negative pressure in the chamber. In the preferred embodiments of the invention, a second sensor is also mounted at location **31** to measure the temperature within the milling chamber. In other embodiments of the invention, the first and second sensors may be located in alternative locations, such as (but not limited to) a location on top of enclosure **18** for conveyor **17**, or adjacent to either end of duct **38** (in machine **1**B, shown in FIG. **2** or machine **1**D, shown in FIG. **4**), or in baghouse **24**. Those having ordinary skill in the art to which the invention relates may choose sensor locations for particular embodiments to obtain the most accurate readings. Displays for these sensors are provided at operator's station **2**.

First conveyor **14** is enclosed by enclosure **15**, which is preferably provided with seals that contact the conveyor belt, commonly called flashings, so that the space above the belt of first conveyor **14** within enclosure **15** defines a first enclosed duct through which a gas stream can pass. This enclosed duct is in communication with the milling chamber so that the combination of the milling chamber and the first enclosed duct comprises an enclosed space.

Milled material is conveyed off the forward end of first conveyor **14** onto second conveyor **17**, and off the forward end of second conveyor **17** (as material **20**) into a truck. Second conveyor **17** is mounted with respect to first conveyor **14** so as to be pivotable about horizontal pivot **29**. A linear actuator (not shown) may be mounted between pivot points **21** and **22** to raise and lower the forward end of second conveyor **17**. Second conveyor **17** also is adapted to pivot about a vertical axis through conveyor connector **23** to the left or to the right with respect to the direction of travel of the milling machine so that its forward end may be moved into alignment with an adjacent truck.

Second conveyor **17** is preferably enclosed by enclosure **18**, which is provided with seals or flashings that contact the conveyor belt so that the space above the belt of second conveyor **17** within enclosure **18** defines a second enclosed duct through which a gas stream can pass. This enclosed duct is in communication with the milling chamber and with the first enclosed duct so that the combination of the milling chamber, the first enclosed duct and the second enclosed duct comprises an enclosed space.

In milling machine **1**A (FIG. **1**) and milling machine **1**C (FIG. **3**), first conveyor **14** and second conveyor **17** are connected by a sealed swivel connection joint **16**. Connection joint **16** allows second conveyor **17** to move left and right and to raise and lower the height of its forward end while maintaining a sealed connection to first conveyor **14**. Thus, these two conveyors and their enclosures form a continuous enclosed duct through which dust, air and other gases are conveyed from the milling chamber onto first conveyor **14**, and then onto second conveyor **17**, as indicated by arrow **34**, without requiring any external hoses. In milling machine, **1**B (FIG. **2**) and milling machine **1**D (FIG. **4**), the swivel connection joint **16** is omitted, and one or more connector hoses **38** are employed to convey gases and entrained dust from the enclosure for first conveyor **14** to the enclosure for second conveyor **17**. In the embodiments of the invention illustrated in FIGS. **2** and **4**, connector hoses **38** comprise a part of the enclosed space which also includes the milling chamber, the first enclosed duct and the second enclosed duct.

In milling machine **1**A and milling machine **1**B, a gas stream blocking device such as adjustable damper plate **19**A (also shown in FIG. **5**) is mounted on support **42** at the forward end of second conveyor **17** so as to be moveable forwards and backwards along axis **44** (shown in FIG. **5**). Locking bolt or pin **43** is provided to cooperate with corresponding holes in damper plate **19**A and support **42** so that the damper plate may be locked in any of multiple positions, provided, however, that the damper plate may not be extended into enclosure **18** far enough to impede the flow of material **20** off of second conveyor **17**. In the alternative, slots may be provided in damper plate **19**A, so that a locking bolt may be placed in any of various positions through the slot in the damper plate and into a hole in support **42** to increase the number of positions that the damper plate may be located within the enclosure. However, it is intended that the damper plate be located with respect to enclosure **18** in a position that will block a substantial portion of the gas flow above material **20** in the enclosure. Consequently, as illustrated in FIG. **5**, adjustable damper plate **19**A helps to keep air **41** at atmospheric pressure from entering the reduced pressure area **40** behind the damper plate. The pressure in area **40** is lower than ambient atmospheric pressure (indicated at **41**) because of the suction created by fan **25** (as described in more detail hereinafter). In other embodiments of the invention (not shown in the drawings), enclosure **18** may be arranged and configured so that there is little space above material stream **20** on second conveyor **17**. In such embodiments, adjustable damper plate **19**A may not be needed.

Another gas stream blocking device such as adjustable damper plate **36**A (shown in FIGS. **2** and **6**) is mounted on support **48** at the rear end of second conveyor **17** on machine **1**B, so as to be moveable forwards and backwards along axis **49**. Locking bolt or pin **50** is provided to cooperate with corresponding holes in damper plate **36**A and support **48** so that the damper plate may be locked in any of multiple positions, provided, however, that the damper plate may not be extended into enclosure **18** far enough to impede the flow of material **47** onto second conveyor **17**. Slots may be provided in damper plate **36**A to allow the damper plate to be locked in an infinite number of positions with respect to support **48**. However, it is intended that the damper plate be located with respect to enclosure **18** in a position that will block a substantial portion of the air flow above material **47** in the enclosure.

Another gas stream blocking device such as adjustable damper plate **19**B is mounted on a support (similar to support **42** shown in FIG. **5**) at the forward end of first conveyor **14** of milling machine **1**B so as to be moveable forwards and backwards along an axis (similar to axis **44** shown in FIG. **5**). A locking bolt or pin (similar to locking pin **43**) is provided to cooperate with corresponding holes in damper plate **19**B and its support so that the second damper plate may be locked in any of multiple positions, provided, however, that this damper plate **19**B may not be extended into enclosure **15** far enough to impede the flow of milled material off of first conveyor **14**. In the alternative, slots may be provided in damper plate **19**B so that the damper plate can be locked in an infinite number of positions with respect to the support. However, it is intended that damper plate **19**B be located with respect to enclosure **15** in a position that will block a substantial portion of the gas flow above the milled material in the enclosure. Adjustable damper plate **19**D (shown in FIG. **4**) is located at the front end of first conveyor **14** on machine **1**D, and is essentially identical to adjustable damper plate **19**B on machine **1**B.

The combination of adjustable damper plate **36**A, adjustable damper plate **19**A and adjustable damper plate **19**B on machine **1**B helps to keep the gas pressure in area **40** (shown in FIGS. **5** and **6**) below that of atmospheric pressure. In other embodiments of the invention (not shown in the drawings), enclosure **18** may be arranged and configured so that there is little space above material stream **47** on second conveyor **17**. In such embodiments, an adjustable damper plate (such as damper plate **36**A of machine **1**B) may not be needed. Similarly, enclosure **15** may be arranged and configured so that there is little space above the milled material stream on first conveyor **14** of machine **1**B. In such embodiments, an adjustable damper plate (such as damper plate **19**B of machine **1**B) may not be needed.

In milling machine **1**C (FIG. **3**) and milling machine **1**D (FIG. **4**), a gas stream blocking device comprising flap seal **19**C is located at the forward end of second conveyor **17** and is illustrated in more detail in FIG. **7**. As shown therein, the static gas pressure inside enclosure **18** is indicated at **40**. This pressure is lower than ambient pressure (indicated at **41**) because of the suction created by fan **25** (as described in more detail hereinafter). Because pressure **40** within the enclosure is lower than pressure **41** on top of the flap seal, there is a downward force on the top of flap seal **19**C which tends to help hold it against the forward end of second conveyor **17** while allowing material **20** to pass under it. In other words the flap seal lets material out, but does not let air in. As shown in FIG. **7**, the raised position of flap seal **19**C when material **20** is passing underneath is indicated at **42**.

Another gas stream blocking device comprising flap seal **36**B is also employed in milling machine **1**D at the rear end of second conveyor **17**. In this location as shown in FIG. **8**, the air pressure on top of the flap seal, indicated at **43**, is slightly lower than atmospheric pressure because of the suction created by fan **25**. As shown in more detail in FIG. **8**, milled material **47** enters second conveyor **17**, passing under flap seal **36**B, thereby raising the flap seal (as indicated at **44**) to allow the material to pass. Preferably, a weight or mass **45** is placed atop flap seal **36**B to hold the flap seal down against the lifting force created by the pressure difference. Another flap seal **19**D, similar in all respects to flap seal **19**C and flap seal **36**B, is mounted at the forward end of first conveyor **14** of milling machine **1**D. The combination of flap seals **36**B, **19**C and **19**D on machine **1**D helps to keep the gas pressure within enclosure **18** above second conveyor **17** below that of atmospheric pressure.

In the milling machines illustrated in FIGS. **1**-**4**, the exhaust gases from engine **3** are directed through exhaust gas treatment device **4**, which may comprise a muffler and/or an emission treatment system such as a diesel particulate filter ("DPF"), a selective catalytic reactor ("SCR") and/or any other treatment device suitable for use in treating the exhaust from engine **3**. Exhaust metering valve **5** is located before the outlet of exhaust stack **6** so that a portion of the high-temperature engine exhaust gases can be intercepted before passing through stack **6**. In milling machines **1**A and **1**C, valve **5** permits exhaust gases to be conveyed via conduit **32** to milling chamber **10**. In milling machines **1**B and **1**D, valve **5** allows a portion of the high-temperature engine exhaust gases to be routed via conduit **37** to enclosure **15** over first conveyor **14**. In either case, the temperature and the dew point of the gases in the enclosed space of the invention will be raised. Controller **70**, which is adapted to control the operation of the invention, can be programmed to operate valve **5** so that engine exhaust gases will only pass through conduit **32** or conduit **37** when fan **25** is operating and milling drum **13** is rotating. Exhaust gases not diverted by valve **5** can be exhausted to the atmosphere through exhaust stack **6**. In other embodiments of the invention (not shown), valve **5** may be replaced with a heat exchanger to transfer heat from the engine exhaust gases to other gases in the system.

FIGS. **9**A and **9**B, **10**A and **10**B, and **11**A and **11**B illustrate three variations of valve **5**, each in two different positions. Other valve styles and methods of control may also be used. For all three embodiments illustrated in FIGS. **9**A and **9**B, **10**A and **10**B, and **11**A and **11**B, exhaust metering valve **5** is located downstream of engine **3** and inlet **60**. Outlet **61** leads to stack **6**, and gas bypass outlet **62** leads to conduit **32** in milling machines **1**A and **1**C, or to conduit **37** in milling machines **1**B and **1**D. The gases passing through gas bypass outlet **62** are mixed with the gases in the enclosed space comprising the milling chamber (FIGS. **1** and **3**) or the enclosure **15** (FIGS. **2** and **4**) to raise the temperature of gases therein above their dew point, thereby minimizing or eliminating mudding buildup in housings, ducts and filters.

Each embodiment of valve **5** comprises one or more dampers **62** that are mounted on damper shafts **64**. The dampers are adapted to be moved between positions in which exhaust gases are allowed to pass through outlet **61** to stack **6** (shown in FIGS. **9**A, **10**A and **11**A) and positions in which at least a portion of the exhaust gases are diverted (shown in FIGS. **9**B, **10**B and **11**B) to conduit **32** (FIGS. **1** and **3**) or conduit **37** (FIGS. **2** and **4**). In the embodiment shown in FIGS. **9**A and **9**B, a damper is placed in both outlet **61** and outlet **62**. Linkage arm **65** connects one damper shaft to another and/or acts as a positioning drive motor (not shown). Connecting link **66** can be adjustable so as to change the relationship of one damper plate to another or to a drive positioning motor. An actuator (not shown) moves the dampers in response to control signals. In the embodiment shown in FIGS. **10**A and **10**B, a single damper is placed in outlet **61**. An actuator (not shown) moves the damper in response to control signals. In the embodiment shown in FIGS. **11**A and **11**B, a single damper is placed in outlet **62**. An actuator (not shown) moves the damper in response to control signals.

In preferred embodiments of the invention, a filter device such as baghouse **24** is mounted on top of enclosure **18**, and an opening or passageway is provided from the enclosure into the baghouse, so that air and other gases entraining dust being conveyed through the enclosed space comprising enclosure **18** will pass upwardly into the baghouse, as indicated by arrow **35**. Fan **25** may be operated by motor **26** to provide a negative pressure in enclosure **18**, thereby drawing gases and entrained dust into baghouse **24**. Fan **25** is located at the outlet end of the baghouse in the embodiments of the invention illustrated in the drawings, and is adapted to be controlled from operator's station **2**. The location of the fan at the outlet end of the baghouse in the embodiments of the invention illustrated in the drawings is advantageous because it allows the fan to operate in clean air and to pull gases and dust through the baghouse. However, the fan could alternatively be placed upstream of the baghouse to blow gases and entrained dust into the baghouse.

In the baghouse, gases entraining dust are drawn through a permeable media. The dust is caught on the media while the gases pass through the media as a clean gas stream to exit the system through stack **27**. A sensor such as a thermocouple may be placed at location **28** or other suitable location on the baghouse to measure the temperature of the gases exiting through stack **27**. In addition, another sensor at the same location could be employed to measure the static pressure in the baghouse. Sensor location **39** allows for the placement of a sensor to measure the temperature of the gases and dust entering baghouse **24**. The pressure difference between sensor location **39** and sensor location **28** represents a "delta P" that reflects the filtering efficiency of the filter media. A sensor for static pressure can also be placed at sensor location **39**. All these sensors are preferably employed to send signals to controller **70** in the machine operator's station **2**. Controller **70** may be used to automatically adjust valve **5** of the invention to control the flow of engine exhaust gas into the enclosed space to prevent the temperature of the gas stream entering baghouse **24** from reaching a predetermined level that has been selected to avoid damaging the filter media in the baghouse.

Various types of filter media may be employed, including polyester, Nomex, cotton, pleated fiber, and the like. The shape of the filter media can be round, round with pleats, oval, nearly rectangular, or of other convenient shapes. Preferably, baghouse **24** employs round or pleated bags made of Nomex. To use the space available in the baghouse most effectively, the bags on the forward end of the baghouse (to the left as shown in FIGS. **1**-**4**) are shorter, and the length of the bags increases towards the rear end of the baghouse. A preferred baghouse includes four bags in each of eight rows. The filter area for a baghouse equipped with a plurality of round bags could be approximately 100 ft^2, whereas for a baghouse equipped with a plurality of pleated bags, the filter area could approach 200 ft^2. For a gas flow to filter area ratio (ft^3/minute)/ft^2 of 10, the system could handle gas flow of up to 1000 ft^3/minute if the baghouse were equipped with round bags, or up to 2000 ft^3/minute if equipped with pleated bags.

Various cleaning means are known and used to remove the dust cake from the surface of the media. Two of the more common are jet pulse cleaning using compressed air and atmospheric module cleaning. Preferably, baghouse **24** includes a jet pulse cleaning system. When such a baghouse cleaning system pulses a row of filter bags to clean them, the dust cake released from the filter media falls downward through the opening between enclosure **18** and the baghouse onto the belt of second conveyor **17**. Of course, it is contemplated within the scope of the invention that the dust collected could be directed to a location other than second conveyor **17**. For example, if the invention were installed on a working machine such as a road stabilizer/reclaimer machine, the dust collected in the baghouse could be directed onto the roadway surface beneath the working machine. In addition, baghouse **24** could be replaced with other filtering devices, including filter houses of various styles and shapes. It could be equipped with any number, style and shape of media and could be cleaned by various methods known to those having ordinary skill in the art to which the invention relates.

The invention facilitates the use of the heat of engine exhaust gases for a useful purpose. In some embodiments of the invention, the direct mixing of engine exhaust gases with other gases in the system can be employed to raise the temperature of such other gases. In the alternative, the invention allows for employing a heat exchanger to extract the heat from engine exhaust gases for use in raising the temperature of other gases in the system. The invention permits the use of the heat of engine exhaust gases, either directly or indirectly, to raise the temperature of other gases which contain dust and condensable gases so that the condensable gases do not condense and cause mudding and plugging of system components. The invention allows for the controlled introduction of engine exhaust gases directly into a milling chamber, and for the use of the space under a conveyor enclosure as a duct for gas transport. The invention also allows for an enclosed space to include the connection in the transfer point between the first and second conveyors so that both the milled material contained on the conveyor belts and the gas and dust entrained in the enclosed space above the belt transfer will be retained within the system. Furthermore, the invention provides low points in the system past which gases are conveyed that are in motion and capable of carrying any dust fall-out. These low points are located in the milling chamber, the first conveyor, the transfer point between conveyors and the second conveyor.

Although this description contains many specifics, these should not be construed as limiting the scope of the invention but as merely providing illustrations of the presently preferred embodiments thereof, as well as the best modes contemplated by the inventors of carrying out the invention. The invention, as described herein, is susceptible to various modifications and adaptations, as would be understood by those having ordinary skill in the art to which the invention relates, and the same are intended to be comprehended within the meaning and range of equivalents of the appended claims.

What is claimed is:

1. A method for operating a working machine which includes:

(a) a drive engine that produces engine exhaust gases;

(b) a milling drum that is mounted for rotation against a road surface thereby generating milled material including dust from the road surface;

(c) an enclosed space within which said milled material is contained;

(d) a spray assembly for directing water in such a manner that, during a period of rotation of the milling drum against the surface of the road, at least a portion of the water is converted to a vapor which is contained within the enclosed space;

(e) an exhaust stack for engine exhaust gases;

(f) a conduit for conducting at least a portion of the engine exhaust gases into the enclosed space;

(g) an exhaust metering valve that is adapted to selectively direct the engine exhaust gases into the conduit for conducting at least a portion of the engine exhaust gases into the enclosed space and/or to the exhaust stack;

(h) a controller that is adapted to operate the exhaust metering valve to control the flow of engine exhaust gases into the enclosed space;

said method comprising:

(i) operating the controller to conduct at least a portion of the engine exhaust gases into the enclosed space to heat the gas stream therein containing vapor and dust from the milled material to a temperature above its dew point.

2. The method of claim **1** which includes conducting the gas stream which has been heated by the engine exhaust gases to a filter device for removal of the dust therefrom.

3. The method of claim **2** which includes the step of controlling the amount of engine exhaust gases that are conducted to the filter device to prevent the temperature of the gas stream entering the filter device from reaching a predetermined level that is selected to avoid damaging the filter device.

4. The method of claim **1** which includes conducting the engine exhaust gases through an exhaust gas treatment device and then conducting at least a portion of the engine exhaust gases from the exhaust gas treatment device into the enclosed space.

5. The method of claim **4** wherein the exhaust gas treatment device is selected from the group consisting of a muffler, a diesel particulate filter and a selective catalytic reactor.

6. A working machine for use in milling the surface of a road, said working machine comprising:

(a) a drive engine that produces engine exhaust gases;

(b) a milling drum that is mounted for rotation against the surface of the road, said milling drum being adapted to generate milled material including dust from the road surface;

(c) a milling chamber within which said milling drum is contained;

(d) a spray assembly for directing water into the milling chamber in such a manner that, during a period of rotation of the milling drum against the surface of the road, at least a portion of the water is converted to a vapor;

(e) an enclosed space which comprises the milling chamber;

(f) a conduit for conducting at least a portion of the engine exhaust gases into the enclosed space to raise the temperature of a gas stream therein containing vapor and dust from the milled material;

(g) an exhaust stack for engine exhaust gases;

(h) an exhaust metering valve that is adapted to selectively direct the engine exhaust gases into the conduit for conducting at least a portion of the engine exhaust gases into the enclosed space and/or to the exhaust stack.

7. The working machine of claim **6**:

(a) which includes a first conveyor for carrying milled material from the milling enclosure;

(b) which includes an enclosure for the first conveyor that defines a first enclosed duct through which a gas stream can pass;

(c) wherein the first enclosed duct is in communication with the milling chamber so as to be included along with the milling chamber within the enclosed space.

8. The working machine of claim **7**:

(a) which includes a second conveyor for carrying milled material from the forward end of the first conveyor;

(b) which includes an enclosure for the second conveyor that defines a second enclosed duct through which a gas stream can pass;

(c) wherein the second enclosed duct is in communication with the first enclosed duct and the milling chamber so as to be included along with the first enclosed duct and the milling chamber within the enclosed space.

9. The working machine of claim **6** which includes:

(a) a fan that is adapted to create negative pressure within the enclosed space;

(b) a controller that is adapted to operate the exhaust metering valve so that engine exhaust gases will only be directed into the conduit for conducting at least a portion of the engine exhaust gases into the enclosed space when the fan is operating and the milling drum is rotating.

10. The working machine of claim **9**:

(a) which includes a filter device that is included within the enclosed space;

(b) wherein the fan is adapted to create negative pressure within the enclosed space and to draw a gas stream from the enclosed space through the filter device.

11. The working machine of claim **10** wherein the controller is adapted to operate the exhaust metering valve to control the flow of engine exhaust gas into the enclosed space to prevent the temperature of the gas stream entering the filter device from reaching a predetermined level that has been selected to avoid damaging the filter device.

12. The working machine of claim **10** wherein the filter device comprises a baghouse having a plurality of filter bags therein.

13. The working machine of claim **12** wherein the filter bags are sized and configured to provide a gas flow to filter area ratio of approximately ten.

14. The working machine of claim **12** wherein the filter bags are arranged in eight rows of four bags each.

15. The working machine of claim **14**, wherein the bags on the forward end of the baghouse are shorter, and the length of the bags increases towards the rear end of the baghouse.

16. A working machine for use in milling the surface of a road, said working machine comprising:

(a) a drive engine that produces engine exhaust gases;

(b) a milling drum that is mounted for rotation against the surface of the road, said milling drum being adapted to generate milled material including dust from the road surface;

(c) a milling chamber within which said milling drum is contained;

(d) a spray assembly for directing water into the milling chamber in such a manner that, during a period of rotation of the milling drum against the surface of the road, at least a portion of the water is converted to a vapor;

(e) an enclosed space which comprises the milling chamber;

(f) a conduit for conducting at least a portion of the engine exhaust gases into the enclosed space to raise the temperature of a gas stream therein containing vapor and dust from the milled material;

(g) a first conveyor for carrying milled material from the milling enclosure;

(h) an enclosure for the first conveyor that defines a first enclosed duct through which a gas stream can pass, said first enclosed duct being in communication with the milling chamber so as to be included along with the milling chamber within the enclosed space;

(i) a second conveyor for carrying milled material from the forward end of the first conveyor;

(j) an enclosure for the second conveyor that defines a second enclosed duct through which a gas stream can pass, said second enclosed duct being in communication with the first enclosed duct and the milling chamber so as to be included along with the first enclosed duct and the milling chamber within the enclosed space;

(k) a first gas stream blocking device at the forward end of the second conveyor, which first gas stream blocking device is adapted:

(i) to block a substantial portion of the gas stream above the milled material on the second conveyor;

(ii) to help to keep air at atmospheric pressure from entering the second enclosed duct.

17. The working machine of claim **16** which includes a second gas stream blocking device at the rear end of the second conveyor, which second gas stream blocking device is adapted to block a substantial portion of the gas stream above the milled material on the second conveyor.

18. The working machine of claim **16** which includes a second gas stream blocking device at the forward end of the first conveyor.

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